

BULLETIN No. 675

AUGUST, 1936

# New York State Agricultural Experiment Station

Geneva, N. Y.

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RETARDED FOLIATION IN BLACK RASPBERRIES  
AND ITS RELATION TO MOSAIC

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PUBLISHED BY THE STATION  
UNDER AUTHORITY OF CORNELL UNIVERSITY

## ABSTRACT

THE discovery was made in the spring of 1932 in western New York that black raspberry plants infected with green mottle mosaic were apt to be retarded considerably in their foliation compared with normal plants. During late April or early May in each spring season of 1933, 1934, and 1935, extensive field records of cases of retarded foliation were made in commercial plantings of black raspberries. Mosaic inspections of the same blocks were made in June each year. The two records were then compared to determine the proportions of (1) mosaic cases that were detected thru delay in foliation, (2) mosaic infections that were not discovered by this method of inspection, and (3) virus-free plants that were backward in spring development. For the most part, these investigations were conducted in plantings of Cumberland and Plum Farmer ranging in age from 1 to 4 years.

High proportions (74 to 94 per cent with a general average of 85 per cent) of the black raspberry plants found systemically infected with green mosaic in June were recorded as having been retarded in foliation in April or May. Yellow mosaic cases discovered by delayed spring development ranged from 9 to 61 per cent, with a general average of only 25 per cent.

In the 1933 experimental blocks, only 0.4 per cent of the virus-free plants were delayed in leafing out; but in 1934, the prevalence of winter injury which caused retarded development confusingly like that produced by mosaic infection, accounted for the inclusion of 16 per cent of virus-free plants in the retarded foliation class. In the 1935 blocks winter injury again was frequent, but careful diagnosis of individual cases reduced the proportion of virus-free plants included in the retarded foliation record to 1.2 per cent without reducing the accuracy of mosaic detection appreciably.

The retarded foliation characteristic is recommended as a basis for a supplementary inspection and roguing in black raspberry plantings where green mosaic control is an important consideration, except in seasons when winter injury is abundant.

In red raspberries neither green mosaic nor yellow mosaic infections resulted in any apparent delay in spring development.

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## RETARDED FOLIATION IN BLACK RASPBERRIES AND ITS RELATION TO MOSAIC

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### INTRODUCTION

Mosaic infections in black raspberries are identified primarily by mottling symptoms on the leaves and secondarily by necrotic effects on the tips of new canes and on the leaf petioles. Naturally then, detection of mosaic-affected plants in the spring has not been possible until after they have made considerable growth and have become well leafed out. This means that in normal seasons in western New York inspections of black raspberry plantings for the purpose of eliminating mosaic are not undertaken until about June 1.

In late April, 1932, in the course of general observations on seasonal development of black raspberries in Erie County, N. Y., certain bushes were noticed as being appreciably tardy in leafing out. These individuals appeared quite conspicuous by contrast with surrounding normal plants (Fig. 1). The differences became increasingly obvious early in May and lasted nearly until June. No relationship between any environmental or cultural factors and the occurrence of plants thus affected was apparent. No evidence of fungous or bacterial parasitism, such as root-rot or crown-gall diseases, could be found to account for the phenomenon; nor were there any indications of winter injury. Mosaic infections were suspected as the most probable cause of the retarded development.

If infections with the mosaic viruses could be detected in black raspberry plants by a typical retardation in their spring development, several advantages would be gained in mosaic control. First, the recognition of mosaics would be made simpler for untrained observers. A gross and conspicuous character like a marked delay in foliation is more apparent than are the detailed symptoms of leaf-mottling and of necrosis of petioles and cane-tips. As a second advantage, mosaic sources would be eliminated before the spring period of greatest

disease spread. Most important of all, however, earlier removal of mosaic cases would reduce the chances of disease spread occurring during the "roguing" process. In late April and early May in western New York, the aphid vectors of raspberry mosaics are rare and the few stem-mothers present are inactive because of the cool weather. At this time, mosaic-infected plants could be removed without giving heed to vector populations. By mid-June in typical seasons, however, the raspberry aphids have increased many fold—hundreds if not thousands of times—have become widely distributed, and are active and easily dislodged from their hosts. At this time, the digging and removal of infected plants from the field incur a high risk of disease spread.

For these reasons, investigations were carried on during four spring seasons, 1932 to 1935, inclusive, to test the accuracy of the delayed foliation character in detecting mosaics and to determine its usefulness as a basis for inspecting and roguing black raspberry plantings.

#### PLAN OF INVESTIGATION

The studies of 1932 consisted simply of watching the development of a few marked plants of Cumberland. The studies made in 1933, 1934, and 1935 were conducted on a more extensive scale and included five varieties of black raspberries in blocks of different sizes and ages and with varying soil types, land contours, and levels of culture. All blocks were located in commercial black raspberry plantings in Erie or Chautauqua counties and in the vicinity of Brant and Silver Creek, respectively.

In each experimental block at the time in the spring when variations in degree of foliation were most apparent (April 24 to May 15, depending on the season), a record was made of the location, by number in the row, of each plant that was backward in development. Only clear-cut, unmistakable cases were included in these delayed foliation inspection records. In June at the optimum season for mosaic detection, another record was made of the exact locations of all but current-season mosaic infections. A comparison of the two records on each block then disclosed three important features, *viz.*, (1) mosaic cases that were detected thru the delay in foliation, (2) mosaic cases that were not discovered by this method of inspection, and (3) virus-free plants that nevertheless were backward in their spring development.

## RECORDS OF 1932

Five black raspberry plants decidedly and typically retarded in foliation were marked in each of three yearling Cumberland fields on May 9, 1932 (Fig. 1). These 15 plants were observed at occasional intervals until June 6 when all were plainly systemic cases of green mottle mosaic or green mosaic.<sup>1</sup>

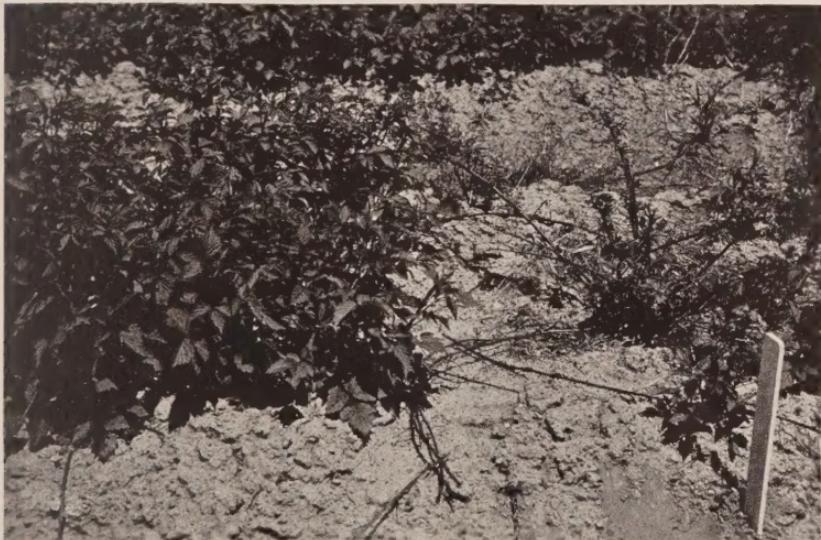


FIG. 1.—RETARDED FOLIATION OF A YEARLING CUMBERLAND BLACK RASPBERRY PLANT (RIGHT) INFECTED WITH GREEN MOSAIC.

Photographed May 23, 1932.

By the latter date, just prior to bloom, the stage of foliation on the fruiting canes of the marked diseased plants had progressed to a point comparable, if not quite equal, to that of their virus-free neighbors. Of course, even mildly affected mosaic plants could then be readily distinguished from healthy individuals by the usual symptoms, i.e., stunting of entire plants, shortened fruit spurs, and smaller and mottled leaves, but the striking difference in general degree of foliation so apparent in early May was no longer visible.

<sup>1</sup>This disease is identical with the one that has been known previously as red raspberry mosaic or red mosaic. The new name, green mottle mosaic, is suggested as preferable for reasons given in the following citation: Cooley, L. M. The identity of raspberry mosaics. *Phytopath.*, **26**: 44-56. 1936.

### RECORDS OF 1933

The 1933 studies were made in 2-year-old plantings of Cumberland and Plum Farmer. The Cumberland plat covered 2,160 plants or approximately one-fifth of a 6-acre commercial field that had received good care but in which, due to differences in elevation and in soil moisture and fertility, the size and vigor of plants varied between wide extremes. The Plum Farmer block contained 2,374 plants, making up about one-fourth of a 5-acre commercial field in which all conditions might be characterized as average and uniform, resulting in raspberry plant growth of the same type. The delayed foliation inspection was made on April 24. Mosaic records were taken June 16 and 28.

The contrast in degree of foliation of two adjacent Cumberland black raspberry plants, one healthy the other mosaic-infected, as they existed on April 24, 1933, is shown in Fig. 2. The data obtained during this season are given in Table 1.

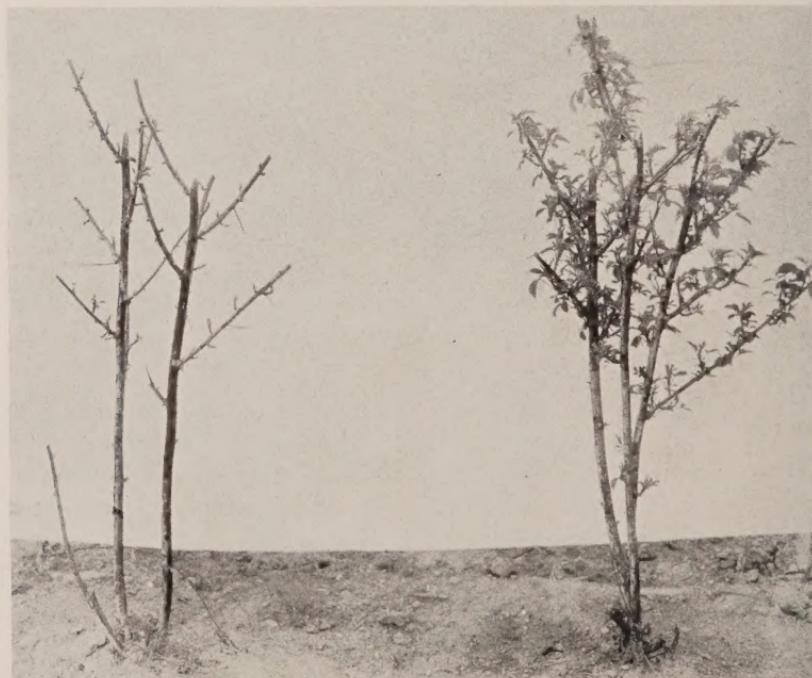


FIG. 2.—COMPARATIVE SPRING DEVELOPMENT OF ADJACENT 2-YEAR-OLD CUMBERLAND BLACK RASPBERRY PLANTS ON APRIL 24, 1933.

On June 16, the plant on the left was found to be a systemic green mosaic case; that on the right was healthy.

TABLE 1.—RETARDED FOLIATION AND MOSAICS IN BLACK RASPBERRIES, 1933.

VARIETY	AGE OF PLANTING, YEARS	No. PLANTS OBSERVED	MOSAIC INFECTIONS*				MOSAIC-FREE PLANTS			
			Green		Yellow		Retarded, April 24		Retarded, April 24	
			No. in June	No.   Per cent	No. in June	No.   Per cent	No. in June	No.   Per cent	No. in June	No.   Per cent
Cumberland.....	2	2,160	313	258†	96	9	1,751	10	0.6	
Plum Farmer.....	2	2,374	228	206‡	41	15	2,105	7	0.3	
Total and av. . . . .	—	4,534	541	464	86	137	15	11	3,856	17
										0.4

\*Infection that by symptom distinctions obviously had taken place during the current spring were not included in this or the following tables.

†This group included five plants infected with both green and yellow mosaic viruses.

‡This group included one double infection with both mosaic viruses and eight plants that died during May in a manner typical of green mosaic infection (Fig. 4).

A large proportion, but not all, of the green mosaic infections proved to have been retarded in the bud development of their fruiting canes. In both blocks combined, 86 per cent (464 of 541 cases) of the systemic cases of this disease present in June had been recorded in the delayed foliation group on April 24. The rate of detection was significantly higher in the Plum Farmer block (90 per cent, or 206 of 228 cases) than in the Cumberland (82 per cent, or 258 of 313 cases).

An unexpectedly small proportion of the established yellow mosaic cases were found to have been included in the retarded class; only 11 per cent (15 of 137 cases). The rate of detection of this disease by the delayed foliation character ran higher in the Plum Farmer block (15 per cent, or 6 of 41 cases) than in the Cumberland block (9 per cent, or 9 of 96 cases).

Comparatively few mosaic-free plants (17 in 3,856, or 0.4 per cent) were recorded in the retarded development group. Most of these were weakly and bore practically no crop in 1933, because of one or more reasons, such as soil infertility, cultivator injury, severe anthracnose infection, or winter injury.

#### RECORDS OF 1934

Portions of seven commercial fields composed the experimental blocks in which the studies of 1934 were made. There were two blocks each of Cumberland and Plum Farmer and one block each of Naples, Seneca, and Shuttleworth. The age of plantings ranged from 1 to 3 years. The size of the blocks ranged from 356 to 960 plants. In all, 4,899 plants were under observation.

Because of the severity of the preceding winter, all raspberry plants were later than usual in starting their spring development in 1934. Therefore, delayed foliation records were not made until May 9, 11, and 15. Mosaic inspections were conducted on June 8, 18, and 29.

Typical contrast in fruiting-cane development between mosaic and healthy Plum Farmer raspberry plants in the spring of 1934 is shown in Fig. 3. Data for this season are given in Table 2.

The rate of detection of green mosaic infections by delay in spring foliation ran from 74 per cent (175 of 237 cases) in the Seneca block to 94 per cent (44 of 47 cases) in the Naples block, with a total rate of 86 per cent (854 of 990 cases) for all five varieties.

Yellow mosaic infections proved again to be much less inclined to delay in bud development. In a total of 159 systemic cases of this

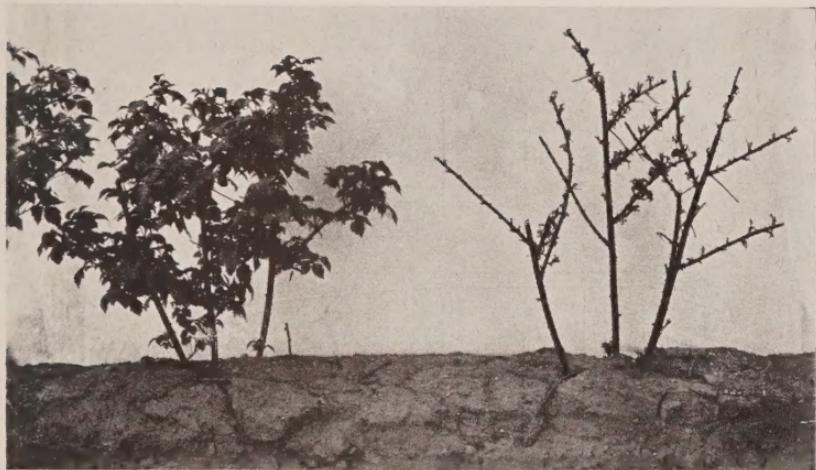


FIG. 3.—COMPARATIVE SPRING DEVELOPMENT OF ADJACENT 2-YEAR-OLD PLUM FARMER BLACK RASPBERRY PLANTS AS SEEN MAY 15, 1934.

The individual on the right was infected systemically with green mosaic; the one on the left was healthy.

disease that were found in June, only 57, or 36 per cent, had been included in the delayed foliation records taken in May. The rate of detection in those blocks where yellow mosaic was present in any considerable proportion varied from 15 per cent in the 3-year-old Cumberland to 61 per cent in the Naples.

An important altho disconcerting development in this season's investigations was the high proportion of mosaic-free plants that were recorded in May as retarded in foliation (592 of 3,750, or 16 per cent). The rate of inclusion of mosaic-free individuals varied from 8 per cent in both Plum Farmer blocks to 44 per cent in the Naples. The delay in bud development on the fruiting canes of these virus-free plants was due in every instance to winter injury resulting from the abnormally cold temperatures that occurred in western New York during December, 1933, and January and February, 1934.

#### RECORDS OF 1935

In 1935 records were taken in two Cumberland blocks, 1 and 4 years old respectively and in two Plum Farmer blocks, likewise 1 and 4 years of age. These blocks were extensive in size, totalling 10,759 plants, and were located in fields where mosaic incidence was relatively low (2.6 to 4.8 per cent).

TABLE 2.—RETARDED FOLIATION AND MOSAICS IN BLACK RASPBERRIES, 1934.\*

VARIETY	AGE OF PLANTING, YEARS	No. PLANTS OBSERVED	MOSAIC INFECTIONS				MOSAIC-FREE PLANTS			
			Green		Yellow		Retarded, May		Retarded, June	
			No. in June	Retarded, May	No. in June	Per cent	No.	Per cent	No.	Per cent
Cumberland.....	3	620	136	121	89	48	7	15	436	102
Cumberland.....	1	960	231	208	90	1	0	0	728	134
Naples.....	2	374	47	44	94	46	28	61	281	123
Plum Farmer.....	3	869	109	99	91	26	8	31	734	58
Plum Farmer.....	2	985	178	160	90	30	11	37	777	59
Seneca.....	3	735	237	175	74	7	2	29	491	80
Shuttleworth.....	3	356	52	47	90	1	1	100	303	36
Total and av.....	—	4,899	990	854	86	159	57	36	3,750	592
										16

\*The delayed foliation records of 1934 included not only plants whose fruiting canes were tardy in bud development, but also those whose fruiting canes had been partially to entirely winter killed.

Owing to a second successive severe winter for western New York, the start of the 1935 raspberry growing season was again delayed 2 to 3 weeks beyond normal and the delayed foliation inspection could not be made until May 14. The mosaic inspection was made on June 18 and 20. The data obtained are presented in Table 3.

Again, a high rate of detection of the green mosaic infections by the retarded development criterion was attained. In both Cumberland blocks, 79 per cent of the cases of this disease were recorded in the delayed foliation class in May. For Plum Farmer, the rate of detection was 92 per cent in the 1-year-old block and 84 per cent in the 4-year-old planting. The total rate of detection of green mosaic for all blocks was 82 per cent.

Yellow mosaic infections were an inconsiderable quantity. Of a total of nine cases only three, or 33 per cent, were included in the delayed development group.

Plants that were mosaic-free in June yet had been included in the delayed foliation group in May numbered 123, or 1.2 per cent of the 10,388 healthy plants. Winter injury was responsible for most of this inclusion of healthy stock in the retarded group.

## DISCUSSION AND CONCLUSIONS

*Retardation and green mosaic.*—A review of the data shows that a consistently high proportion of the black raspberry plants affected with green mosaic were retarded characteristically in their fruiting cane development. The rate of detection of this disease by this criterion ranged in the different experimental blocks from 74 to 94 per cent, with a 3-year average of 85 per cent.

These percentage rates of detection, considering the regularity with which they were obtained, would seem to justify using retardation as a basis for removing green mosaic-infected plants from black raspberry fields in which virus control is being attempted. The converse result, i.e., that never were all of the systemic infections of green mosaic retarded in their spring development, also has a direct bearing on how this finding should be used. These and other similar points are discussed more fully on page 18.

*Retardation in relation to the severity of green mosaic.*—Green mosaic infections in black raspberries vary widely in severity. When the records in the experimental blocks of 1933 showed that 10 per cent of the affected Plum Farmer plants and 18 per cent of the affected

TABLE 3.—RETARDED FOLIATION AND MOSAICS IN BLACK RASPBERRIES, 1935.

Cumberland plants had escaped detection in the retarded foliation inspection (Table 1), the logical explanation appeared to be that of variations in disease severity. That is, the mildest cases of green mosaic presumably had not exhibited any delay in spring development, or their difference from normal foliation had been so slight as to escape notice. To test the validity of this assumption, a second mosaic inspection was made in early July, 1933, over the same experimental blocks. This time all systemic infections with the green mosaic virus were not only recorded but were classified, relatively and arbitrarily, as either mild, medium, or severe. This classified disease record was then compared with the delayed foliation record obtained on April 24 with the result given in Table 4.

TABLE 4.—THE RELATION OF THE DISEASE SEVERITY OF GREEN MOSAIC TO RETARDED FOLIATION IN BLACK RASPBERRIES, 1933.

DISEASE TYPES OF GREEN MOSAIC	CUMBERLAND			PLUM FARMER		
	No. of cases, July	Retarded, April 24	Per cent	No. of cases, July	Retarded, April 24	Per cent
Mild.....	80	57	71	36	27	75
Per cent of total.....	26	—	—	16	—	—
Medium.....	119	94	79	38	33	87
Per cent of total.....	38	—	—	17	—	—
Severe*.....	114	107	94	154	146	95
Per cent of total.....	36	—	—	67	—	—
Total and av.....	313	258	82	228	206	90

\*Double infections and deaths were included in this group.

In both blocks, the highest rate of green mosaic detection was achieved in the severely affected class, *viz.*, 94 per cent in the Cumberland and 95 per cent in the Plum Farmer. The rate of detection of medium cases ran 79 percent in the Cumberland and 87 percent in the Plum Farmer, and in the mild infections, 71 per cent and 75 per cent, respectively. This trend indicates that increased severity of green mosaic infection in black raspberry plants enhances the probability of their delay in spring foliation. But the original assumption that all the infections escaping detection in the retarded foliation inspection would be those of the mildest type was not borne out. Apparently, severity of infection alone does not account for the retarded foliation phenomenon.

Incidentally, the proportions of the three disease types in this

experiment were representative of the relative susceptibility<sup>2</sup> of the two varieties in western New York. Among black raspberries Cumberland is classed relatively as green mosaic resistant and Plum Farmer as green mosaic susceptible. In these records (Table 4), 26 per cent of the green mosaic infections in Cumberland were classed as mild, 38 per cent as medium, and 36 per cent as severe. In Plum Farmer, 16 per cent were classed as mild, 17 per cent as medium, and 67 per cent as severe.

*Retardation by green mosaic in relation to black raspberry varieties.*—As noted above, in 1933 the proportion of the green mosaic infections detected by retarded development was significantly greater in the susceptible Plum Farmer than in the more resistant Cumberland—90 per cent as compared to 82 per cent (Table 1). In 1934, again the rate of disease detection was higher in the Plum Farmer blocks than in the Cumberland, but the difference was only 1 per cent (Table 2). In 1935, the rate of detection averaged 9 per cent higher in the Plum Farmer blocks (Table 3). In the case of the blocks of the three other less widely grown varieties included in the 1934 investigations, the accuracy of green mosaic detection by delayed foliation was highest (94 per cent) in the Naples, a most susceptible sort, and lowest (74 per cent) in the Seneca, a resistant kind (Table 2).

These results suggest that in relatively susceptible black raspberry varieties approximately 9 of 10 green mosaic infections present will be discoverable by retarded fruiting cane development, while in the relatively resistant varieties the ratio will be about 3 of 4 or 4 of 5.

*Retardation and yellow mosaic.*—Yellow mosaic is less common than green mosaic in black raspberries, but as a general rule, it is much the more injurious. Contrary to expectations, experimental records showed that the delayed foliation criterion has little value, comparatively, in the discovery of yellow mosaic infections. In those experimental blocks where this disease was present in any quantity, the rate of detection ranged from 9 to 61 per cent. Of the total number of 305 yellow mosaic cases encountered in these investigations, only 75, or slightly less than 25 per cent, were included in the retarded-development group. Such a ratio is far too low to warrant a special inspection for this disease alone. Under western New York conditions, however, the elimination of some of the yellow mosaic infections

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<sup>2</sup>In all instances where the terms resistant and susceptible are used in this publication they refer to the reaction of the host plant *after virus infection has taken place.*

along with the majority of the more prevalent green mosaic infections is worth considering.

*Action of the mosaic viruses in causing retardation of foliage.*—Since some of the most severely affected green mosaic cases were not retarded in foliation, at least not sufficiently to have been noted, and since the more severe disease of yellow mosaic caused a lower ratio of retardation, disease severity does not seem to account for the delayed foliation phenomenon. Movement of the viruses within the raspberry plants appears to be the crucial factor governing delay in development of fruit cane buds.

On such an hypothesis the seeming paradox in the action of the two mosaic viruses can be readily explained. Bennett<sup>3</sup> has proved experimentally that the virus of green mosaic becomes active at lower temperatures and moves much more rapidly within the host plant than does the yellow mosaic virus. The green mosaic virus is apparently able to move into and along with the growing points of the raspberry plants, the buds, early in the spring. Its presence there is reflected in a decelerated rate of growth or even death (Fig. 4) of these sensitive embryonic tissues. The yellow mosaic virus, altho eventually more harmful to its host, causes fewer cases of delay in spring development presumably because of its later start and slower rate of movement.

Conceivably, thru anatomical and physiological host-parasite

<sup>3</sup>Bennett, C. W. Further observations and experiments with mosaic diseases of raspberries, blackberries, and dewberries. *Michigan Agr. Exp. Sta. Tech. Bul.* No. 125. 1932.



FIG. 4.—A TYPICAL EFFECT OF GREEN MOSAIC ON THE FRUITING CANE OF A BLACK RASPBERRY PLANT.

The fruit spur buds on this Plum Farmer cane had just initiated a tardy development when all of them died, simultaneously and suddenly. This cane was on a plant known to have been systemically infected in the previous growing season. Dissection of the buds showed a necrotic condition strikingly like that commonly seen on turion cane tips of mosaic plants in mid-summer. This phenomenon has been widely observed in several varieties of black raspberries, both in conjunction with and in the absence of winter injury. Photographed May 16, 1934.

relationships not understood at present, the time and rate of movement of a virus might vary with different infected individual raspberry plants. This assumption would explain why a full correlation between disease severity and retardation was not obtained in the experiment with green mosaic, while the likelihood of retardation increased as severity of infection increased. It would also provide an explanation for the small proportion of plants infected with the slower acting yellow mosaic virus that were retarded in development.

*Degree of retardation and its constancy.*—The vast majority of retarded foliation cases caused by mosaic that were met with in this work were just as clearly differentiated from normal foliation as those illustrated in Figs. 1, 2, and 3. However, as might be anticipated from the discussions above, some gradations between typically retarded and normal plants occurred in every one of the experimental blocks. Doubtful or "border-line" cases were more numerous in the blocks of the more resistant varieties, but in none did they present any consequential perplexity. As a general experience, delayed foliation records were taken more easily and rapidly in the susceptible Plum Farmer than in the resistant Cumberland. The margin of contrast in leafing out between healthy and mosaic plants was not only more uniform in the former but was generally greater.

Also, the inspection for delayed foliation always seemed somewhat easier in the yearling than in the older fields. Demarcations between normal and retarded plants seemingly became less pronounced with increased age of plantings. Age of planting, however, at least up to 4 years and excepting the one instance of the Plum Farmer blocks of 1935, apparently had little effect on the accuracy of discovering mosaic infections by retardation in development.

*Retardation in virus-free plants.*—Winter injury was the only natural agency other than viruses that appeared in these investigations as capable of inducing retarded foliation in black raspberry plants similar to that caused by mosaic infection. When winter injury was not prevalent in the experimental blocks, few virus-free plants were included in the retarded class. For instance, in 1933, a normal season, only 17 of 3,856 healthy plants were so classified (Table 1). But when winter damage was general, retarded foliation characterized many healthy plants as well as those infected with mosaic. The records of 1934 (Table 2) exemplify this, when 16 per cent of the healthy plants were classified in the retarded group.

Observations generally have established the fact that mosaic-

affected raspberry plants are more subject to winter damage than virus-free plants. This was the case in the experimental blocks in these investigations; consequently, it might be supposed that severe winter temperatures would only accentuate the difference in spring development between diseased and healthy individual black raspberry plants. This would undoubtedly hold true if there were not frequent exceptions to the general rule and if other factors than mosaic infection, such as immaturity of wood, poor air or soil drainage, anthracnose infections, insect infestations, etc., did not also predispose raspberry plants to injury from low temperatures. As it was, low-temperature damage to the wood of black raspberry fruiting canes was found to produce all degrees of delayed spring foliation in virus-free plants. Naturally, this confused the typically clear demarcations in leafing out between mosaic and healthy plants and not only made the taking of delayed foliation records more difficult, but caused the inclusion of many virus-free plants along with the mosaic-affected plants in the retarded development class.

Profiting by the experience of 1934, however, in 1935, when winter injury was again common in the experimental blocks, a fair measure of success was achieved in distinguishing between retarded development caused by mosaic and that caused by low-temperature damage to cane wood. As evidence of this, only 1.2 per cent of the virus-free but winter-injured plants were included erroneously with the mosaic-affected plants in the delayed foliation group, while almost as accurate detection of green mosaic cases was obtained as in the ideal season of 1933 (compare Tables 1 and 3). The basis on which delayed foliation cases caused by winter injury were segregated from those caused by mosaic consisted primarily of differences in uniformity or completeness of infection in the individual plant. Cases of the former type were characterized by irregularity in degree of retardation of different canes on the same plant and even of individual branches and buds on the same cane. Retardation due to mosaic infection was almost always expressed uniformly over the entire plant. Also, under the conditions of the experimental blocks in 1934 and 1935, almost all cases where complete death of fruiting canes occurred proved to be due to the combined action of mosaic infection and winter temperatures.

*Retardation in relation to virus diseases other than mosaics and to raspberry species other than black raspberry.*—The use of retarded development as an indicator of virus infections in raspberries is limited, as yet, to the one disease of green mosaic in black raspberries.

As remarked above, the delayed foliation criterion seems to have but slight value in the detection of yellow mosaic infections, even in the susceptible black raspberry. The other virus diseases of raspberries, such as the leaf curls and streaks, are of infrequent occurrence in western New York so no observations of their effects on the spring development of their hosts were possible.

Several plantings of red raspberries, in all of which both mosaic diseases were common, were kept under close surveillance during April and May of each year of this work. The varieties represented were Cuthbert, Latham, Ontario, June, Viking, and Adams 87. No differences between individual plants in time or rate of spring foliation, attributable to mosaic infections, were ever noted in any of these varieties.

Only one purple raspberry variety, the Columbian, is planted extensively in western New York. All stock of this variety, so far as observed, is infected completely with the green mosaic virus; consequently no comparisons of spring foliation between healthy and mosaic plants could be made in the purple species.

#### PRACTICAL APPLICATION

The results of these studies on the phenomenon of retarded foliation seem to warrant recommending that, for small fruit sections where green mosaic is an important raspberry virus trouble, an inspection and roguing operation be conducted in black raspberry plantings at the very beginning of each growing season. This inspection should not be relied on however, to replace the more accurate later spring and summer inspections for mosaic, because an appreciable proportion (10 to 25 per cent) of the mosaic cases apparently cannot be discovered in a retarded foliation inspection. Rather, it should prove to be, for reasons stated earlier, a valuable auxiliary in mosaic control. As with the customary inspections for mosaic in raspberries, this supplementary or auxiliary inspection is recommended for use only in plantings where the virus content is low, that is ordinarily 5 per cent or less, and where isolation from outside infection sources is sufficient to insure that no appreciable disease invasion will be likely to occur.

A delayed foliation inspection should be timed as early in the spring as sufficient differentiation has been reached to make it readily possible. In normal seasons in western New York this will be the last week in April; in late seasons it will be early May. The duration of the optimum season for inspection will be about two weeks.

Canes of winter-injured but virus-free bushes will be erratically delayed in foliation. Removal of such plants should be avoided for, altho they will bear little or no fruit in the ensuing season, they will produce normal or even better than normal growth of new canes from the uninjured crowns and these will yield a full crop in the succeeding year. If winter-injured plants are removed in a retarded foliation inspection and then replaced by new sets, two or three years will pass before the latter reach full production. Consequently, in commercial fields, any considerable erroneous removal of winter-injured but virus-free plants occasions serious economic loss. When it is suspected that extensive winter injury has occurred in a black raspberry field where a delayed foliation inspection has been projected, it would perhaps be wiser to abandon the inspection rather than risk the loss of many healthy plants.

A delayed foliation inspection for removal of mosaic-affected plants does not appear to be applicable to red raspberries.

#### SUMMARY

Four seasons of observation (1932 to 1935) in western New York have demonstrated that black raspberry plants infected with the green mottle mosaic virus tend to be retarded in development of foliage on their fruiting canes in the spring. From three-fourths to nine-tenths of the infected plants were detected by this criterion.

The delayed foliation characteristic is sufficiently prominent so that it may well be used as the basis for an auxiliary inspection and roguing in black raspberry plantings where virus disease control is being attempted. Such early season removal gets rid of internal infection sources before the aphid vectors have become numerous and active.

Percentage rates of detection of green mosaic infections on the delayed foliation basis were generally, but not fully, correlated with severity of infection, that is, a higher proportion of the severe than of the medium and of the medium than of the mild cases were retarded in development. Time and rate of movement of the virus within the plant, rather than disease severity, probably determines the retardation effect.

Retarded foliation inspections were more accurate in the detection of green mosaic and were made more easily in plantings of susceptible varieties, such as Plum Farmer, than in plantings of more resistant sorts, such as Cumberland.

Mosaic-free plants were uniform in their time and rate of foliation, except when they were winter injured. In two of the four seasons, winter injury caused retarded development of numerous healthy black raspberry plants in the experimental blocks. Retardation due to this factor oftentimes confusingly resembled that caused by infection with green mosaic.

Only a low proportion of the yellow mosaic infections in black raspberries were reflected in retarded spring development.

No observations on retardation were possible with the leaf curl and streak virus diseases, owing to the infrequency of their occurrence.

Infections with either mosaic virus did not cause any apparent delay of foliation in red raspberries.